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National Park Service
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Natural Resource Program Center

Sand Creek Massacre National Historic Site

Prairie Dog Management Plan and Environmental Assessment

Natural Resource Report NPS/SOPN/NRR—2008/001

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ON THE COVER
A black-tailed prairie dog stands guard at its burrow.
Photograph by: John Sovell, CNHP

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Natural Resource Report NPS/SOPN/NRR—2008/001

Sovell, John
Colorado Natural Heritage Program
Colorado State University
254 General Services Building
Fort Collins, CO 80523

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Introduction

Sand Creek Massacre National Historic Site (SAND) was authorized by the U. S. Congress in November of 2000 with an area of 12,500 acres for inclusion in the park boundaries (Figure 1). Current land acquisitions have resulted in an established boundary that encompasses approximately 2,400 acres (referred to as SAND or The Park in this report) (Figure 1), which is managed by the National Park Service (NPS). The NPS will act to procure additional private land within the authorized boundary as that land becomes available. SAND is on the high plains of southeastern Colorado. It is in north-central Kiowa County near the border with Cheyenne County and is located 14 miles NNE of Eads, Colorado (Figure 1). Kiowa County borders Kansas and SAND is approximately 25 miles from the Kansas state-line. SAND is surrounded by dryland agricultural fields and rangeland. The objective of the NPS is to preserve, protect, interpret, commemorate and memorialize the site for future generations. This includes preservation of the native biological resources of the site.

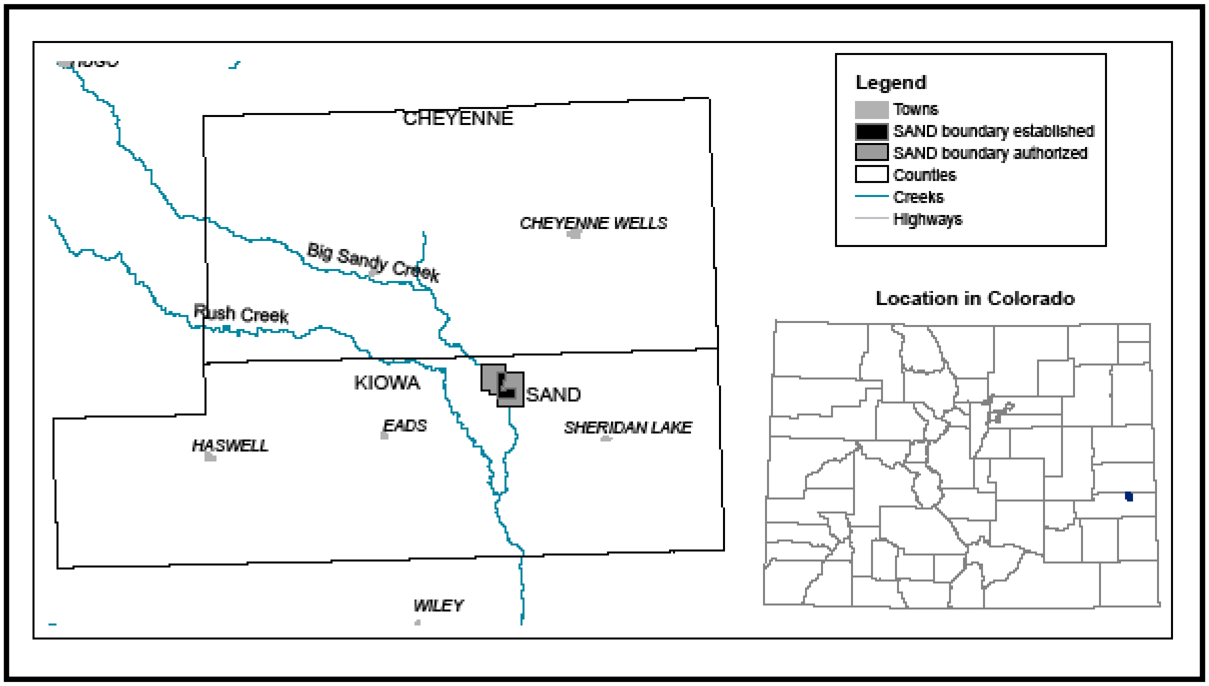

Figure 1. The location of Sand Creek Massacre National Historic Site in Colorado.

SAND is on the High Plains of southeastern Colorado. The primary habitat at the park is shortgrass prairie and sandsage shrubland with the intermittent Big Sandy Creek bisecting the park (Figure 2). Shortgrass prairie occurs on the loamier north side of the Big Sandy. Best expressions of shortgrass prairie occur on flat, ancient, alluvial terraces adjacent to the riparian corridor and on gently undulating uplands north and east of the riparian corridor (Neid et al. 2007). The grassland is characterized by *Buchloe dactyloides* and sod-forming *Bouteloua gracilis*. There is an estimated 347 acres of this grassland type within the current established boundary of SAND, and 3,245 acres within the area authorized for SAND (CNHP 2008). The shortgrass prairie is excellent habitat for the black-tailed prairie dog (*Cynomys ludovicianus).*

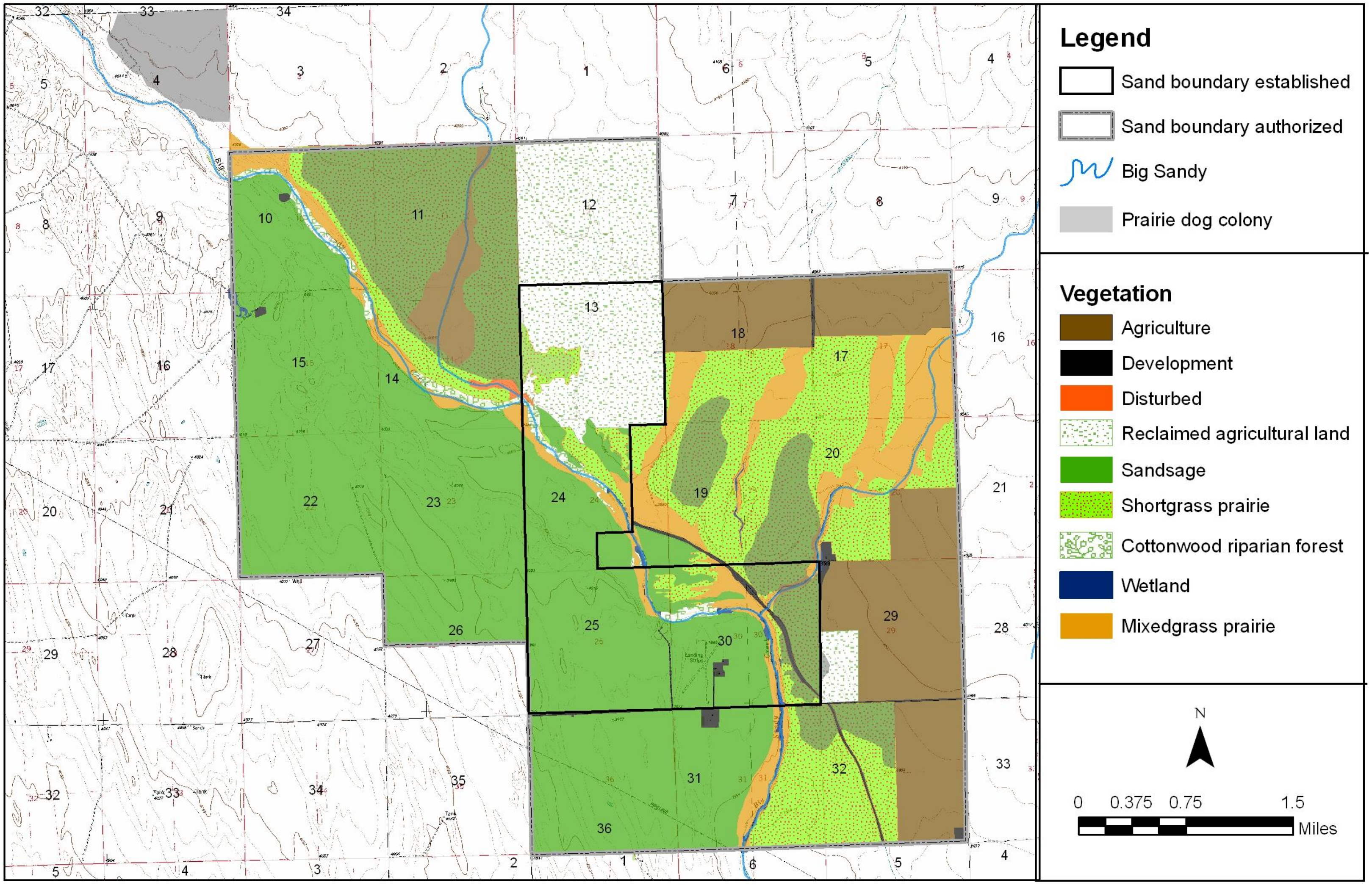

Figure 2. Vegetation map of Sand Creek Massacre National Historic Site showing the location of the black-tailed prairie dog colonies.

Sand sagebrush occupies the sandhills to the south and west of Big Sandy Creek, while the riparian corridor is a mosaic of cottonwood woodland, mesic grassland, and wet meadow surrounding a narrow, braided stream channel (Figure 2) (Neid et al. 2007). There are agricultural fields and reclaimed agricultural fields in the immediate vicinity, especially to the north and east. Soils are well-drained and generally loamy with variable areas of sandy loam, silt loam, and silty or sandy clay loam. On the ancient, alluvial terraces, there are more alkaline indicators.

A prairie dog complex occupies an estimated 228 acres of The Park with average density of the complex estimated at 94 prairie dogs/acre (Sovell 2007). Burrowing owls (*Athene cunicularia*) occur on the prairie dog complex at SAND and mountain plover (*Charadrius montanus*) have been recorded within the complex, but just off The Park (Sovell 2007). Within The Park there are numerous dens of American badgers (*Taxidea taxus*) and coyotes (*Canis latrans*), and ferruginous hawks (*Buteo regalis*) have been recorded in the vicinity of the park (Sovell 2007); all of these species are predators of prairie dogs.

Prairie dogs are important to the proper functioning of native shortgrass prairies and have been proposed as keystone species in North American grasslands (Miller et al. 1994). As a keystone species, prairie dogs impact grassland ecosystems by increasing habitat heterogeneity, modifying ecosystem processes, and enhancing regional biodiversity (Ceballos et al. 1999). There are three primary pathways that prairie dogs exert their influence on shortgrass prairies: through grazing, burrowing, and by acting as prey for other species (Hooglund 2006). Many species use prairie dog colony-sites for food and shelter including American badgers, black-footed ferrets (*Mustela nigripes*), coyotes, ferruginous hawks, golden eagles (*Aquila chrysaetos*), prairie falcons (*Falco mexicanus*), burrowing owls, prairie rattlesnakes (*Crotalus viridis*), and tiger salamanders (*Ambystoma tigrinum*) (Hooglund 1996). Clipping of vegetation and grazing by prairie dogs creates open habitats preferred by grassland birds like mountain plover and horned larks (*Eremophila alpestris*) (Dreitz 2005). The viewpoint that prairie dogs act as keystone species, however, is not without controversy. Knowledge of the effects prairie dogs have on grassland ecosystems may be more limited and equivocal than has been proposed (Stapp 1998). Stapp (1998) suggests, given the variation in grasslands inhabited by prairie dogs (e.g. mixed vs. shortgrass prairies), that they may affect the flora and fauna of these systems in variable ways not yet fully understood. That prairie dogs have effects on many animals is acknowledged (Kotiliar et al. 1999), and their impacts on animal and plant communities are disproportionately large relative to their abundance. Consequently, prairie dogs are critical to the integrity of the shortgrass prairie (Hooglund 2006) and efforts directed towards their conservation will positively impact the grassland ecosystem and grassland species.

The policy of the NPS is to conserve and recover the black-tailed prairie dog wherever possible. Control of prairie dogs on NPS property is allowed only for purposes of human health and safety, good neighbor relations, and to reduce conflicts with other park objectives such as the preservation of cultural resources.

Plan goal

The primary goal of the Sand Creek Massacre National Historic Site (SAND) Black-tailed Prairie Dog Management Plan is to manage for long-term, self-sustaining prairie dog populations at SAND while avoiding negative impacts to landowners that do not wish to accommodate prairie dogs on their properties. An associated effect of the Plan is the increased long-term viability of species closely dependent on the prairie dog ecosystem.

Plan objectives

Objective 1: Document the status and history of prairie dogs at SAND
Objective 2: Identify the future estimated population trends of the prairie dogs at SAND given the current ecological and climate conditions
Objective 3: Identify strategies for within and outside of SAND that have proven to be effective in managing prairie dogs
Objective 4: Determine a population goal for prairie dogs at SAND.
Objective 5: Define the potential future impacts resulting from the use of the identified control strategies such as future changes in prairie dog population sizes, future expansion dynamics of prairie dogs, and changes to local plant community structure within the confined prairie dog towns.
Objective 6: Determine an effective tool to monitor changes in estimated occupied acreage.
Objective 7: Use adaptive management method to evaluate progress of prairie dog planning effort and adjust as needed to accomplish program goals.
Objective 8: Identify and implement management actions that provide environmentally sound habitat for a sustainable population of healthy prairie dogs acceptable to landowners and managers at SAND.

Federal Status of the Black-tailed Prairie Dog

In 1998 the United States Fish and Wildlife Service (Service) received a petition to list the black-tailed prairie dog as threatened throughout its range. Subsequent to the petition for listing, the Service initiated a status review of the prairie dog and upon its completion in 2000, determined that listing of the black-tailed prairie dog was warranted but precluded by higher listing priorities. At that time the species was designated as a federal candidate for listing. Candidate species status was based on the significant threats including sylvatic plague, habitat loss due to urbanization and conversion of grassland to farmland, and inadequate regulatory mechanisms, which have resulted in general declines in prairie dog populations since 1980 (Luce 2003). Resent estimates for Colorado indicate that the State's prairie dog population is either stable or growing slightly in acreage (White 2005). Most states within the current range of the prairie dog, including Colorado, designate this species as a pest species. Statutes within a few of these states require eradication of prairie dogs (Luce 2003), which has resulted in a range-wide lack of adequate regulatory mechanisms for prairie dogs.

In 2004 the Service removed the black-tailed prairie dog from the Federal candidate list. This determination was based on new information about the range-wide impact of disease, chemical control and other lesser factors, as well as higher estimates of the number of acres of occupied black-tailed prairie dog habitat. The Service determined that the prairie dog is not likely to become an endangered species within the foreseeable future and no longer meets the Endangered Species Act definition of threatened (USFWS 2004).

The Status and History of Prairie Dogs in Colorado and at SAND

Estimates for the historical number of acres occupied by black-tailed prairie dogs in Colorado ranges from 3 million to 7 million acres (Clark 1989, Knowles 1998). Current estimates place the number at about 631,102 acres (White et al. 2005), suggesting about a 10-fold decline in the number of acres occupied by prairie dogs in Colorado.

Approximately 6,600 acres of black-tailed prairie dog occupied habitat exist on lands managed by the NPS (USFWS 2004). The NPS policy is to conserve and recover the species wherever possible. It is the desire of the NPS to sustain prairie dog populations at SAND while avoiding negative impacts to landowners who do not wish to accommodate prairie dogs on their properties.

Although the overall historical trend has been for a decline in the number of prairie dogs in Eastern Colorado, which has been attributed to plague and conversion of native prairie to other uses, some prairie dog populations have increased in size. Trend information at the Comanche National Grasslands within the vicinity of SAND, indicates that occupied habitat has increased. Cully and Johnson (2002) estimated 5,886 acres of occupied habitat at Comanche National Grasslands, a 36 percent increase from 2001 when 4,342 acres were estimated as occupied. Long-term trends are provided for the Comanche National Grasslands in Table 1 (USFWS 2004).

Table 1. Summary of Site-Specific Estimates of Black-tailed Prairie Dog Occupied Habitat (estimates in acres) at the Comanche National Grassland from 1980 to 2002.

	Year				
	1980	**1998**	**1999**	**2001**	**2002**
Acres	1,804	1,374	1,974	4,342	5,886

Interviews with local landowners who own property adjacent to SAND indicate that prairie dog colonies within the area surrounding SAND have expanded in size over the last decade, similar to the increases observed within the Comanche National Grasslands. Prairie dogs have been present to the northwest of SAND since the 1980s in the north-central portion of Section 11, Township 17, Range 46. Photographs from the National Aerial Photography Program indicate that in 1989 prairie dogs occupied an estimated 65 acres of shortgrass prairie in section 11. From aerial photographs taken in 1998 it is estimated that prairie dogs occupied 405 acres in section 11 and had expanded into section 4 where they occupied an additional 120 acres. By 2006 the town had expanded onto SAND and covered a total estimated area of 1,453 acres (41 acres within SAND) and was present in sections 4, 10, 11, 13 and 14 of township 17, range 46 (Figure 2). This colony is referred to as the north colony in this report

A prairie dog town also exists in the southeast corner of SAND (referred to as the "south colony" in this report). Aerial photography indicates that this town was not present in 1989 or 1998. However, by 2001 prairie dogs occupied an estimated 60 acres within what is now the established boundary of SAND in Section 30, Township 17, Range 45. At this time there is no evidence in the aerial photographs that prairie dogs existed on the private land adjacent to what is now SAND. By 2006 monitoring of the prairie dog towns at SAND recorded that the south colony had expanded to include 187 acres within SAND and had moved onto private land in Sections 19, 29, 31 and 32 of Township 17, Range 45 (Figure 2).

In summary, the north prairie dog colony at SAND expanded from private land in Section 14 onto The Park, while the south colony originated within the current boundary of SAND sometime after 1998 and has expanded from the park onto adjacent private lands.

Expected Future Estimated Population Trends of the Prairie Dogs at SAND Given the Current Ecological and Climatic Conditions

Evidence from aerial photographs suggests that the prairie dog complex at, and surrounding, SAND is expanding. The two prairie dog colonies at SAND are young colonies, each of which is surrounded by some shortgrass prairie that is suitable for colony expansion. The northern colony appears to be expanding into section 13 within SAND from the adjacent private land of section 14. The majority of section 13 consists of reclaimed agricultural land that contains mixedgrass prairie comprised of native grasses that are suitable for colony expansion as well as weedy patches (Neid et al. 2007). In this habitat the native grasses predominantly include blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), with very little buffalograss (*Buchloe dactyloides*). Although the shortgrass prairie native to the area is predominantly comprised of blue grama and buffalograss, which is preferred by prairie dogs, they are likely to continue their expansion in section 13 into the reclaimed agricultural land. The rate of expansion may be slower than it would be on native shortgrass prairie, particularly during wetter years, because some grasses found in the reclaimed land are denser and taller than either blue grama or buffalograss.

The south colony has occupied nearly the entire suitable shortgrass prairie habitat east of the Big Sandy and the Chivington Ditch within the boundary of SAND. Lands west of the Big Sandy and Chivington Ditch consist of a mixture of sandsage and grasses, and are less suitable habitat for prairie dogs. Property to the north and south of the SAND boundary and lands adjacent to the south colony consist of native shortgrass prairie, very suitable to prairie dogs. Property to the east of the south colony is plowed agricultural land that the prairie dogs have expanded into in recent years.

Research on expanding prairie dog complexes indicates there is a lot of variation in the rates at which colonies expand. However it can be stated with some degree of certainty that the complex at SAND, if left undisturbed, will continue to expand in the foreseeable future. The expansion of prairie dog colonies can be influenced by a number of factors including the amount of rainfall and the subsequent effects that soil moisture has on the height of ground vegetation. At higher rates of precipitation prairie dog colonies expand at lower rates, while during periods of below average rainfall or drought prairie dog colonies tend to increase their rates of expansion (Augustine et al 2007). It is surmised that this occurs because tall, dense vegetation that grows during periods of high annual precipitation impedes visibility, and prairie dogs will not expand into suitable habitat if there lines of view into it are obstructed. In addition, visual contact assists prairie dogs with the identification of potential ground and aerial predators (Franklin and Garret 1989, Hygnstrom 1995). Loss of these view-lines tends to impede prairie dog expansion (Terrall 2006). The reverse occurs during periods of drought (Vermiere 2004).

The current vegetation community near prairie dog towns at SAND includes shortgrass prairie and reclaimed agricultural land containing mixedgrass prairie, which should facilitate expansion of SAND's prairie dog complex. As mention in the previous paragraph, it is thought that drought will facilitate this expansion (Vermiere et al. 2004, Knowles 1986), while higher than average rainfall will retard it (Reading and Matchett 1997).

Climatic conditions at SAND since 1999 have been characterized by below normal rates of precipitation with drought or abnormally dry conditions in June during the growing season (Figure 3). Given the vegetation characteristics at SAND and the recent history of drought in eastern Colorado, it is the author's opinion that without implementation of a control program, the prairie dog complex at SAND will exhibit natural population expansion in the future. When prairie dogs are at high density, with suitable unoccupied habitat at the colony edge, and with favorable climatic conditions affording high visibility into that habitat, their colonies will expand rapidly. The first two conditions occur at SAND and the third condition is likely to occur in at least some future years supplying the prairie dog complex at SAND the opportunity to rapidly expand. The rate at which this recovery will occur is difficult to state with certainty. Prairie dogs under certain conditions, however, have exhibited extremely high rates of expansion. Colonies that have been observed for a year or longer exhibit rates of expansion in the area they occupy of anywhere from 40% to over 100% (Uresk and Schenbeck 1987, Garret and Franklin 1989, Hooglund 1995). The complex at SAND could undergo similar rates of expansion if it is not controlled.

Control efforts on the part of the NPS are likely to create a dynamic that should favor rapid recovery of the complex to pre-control population sizes. Prairie dog removal will result in an increase in resources available for exploitation by newborns, leading to higher rates of recruitment for the first few years immediately following control (Hooglund 2006). The effect will be rapid recovery of the prairie dogs to pre-control abundances.

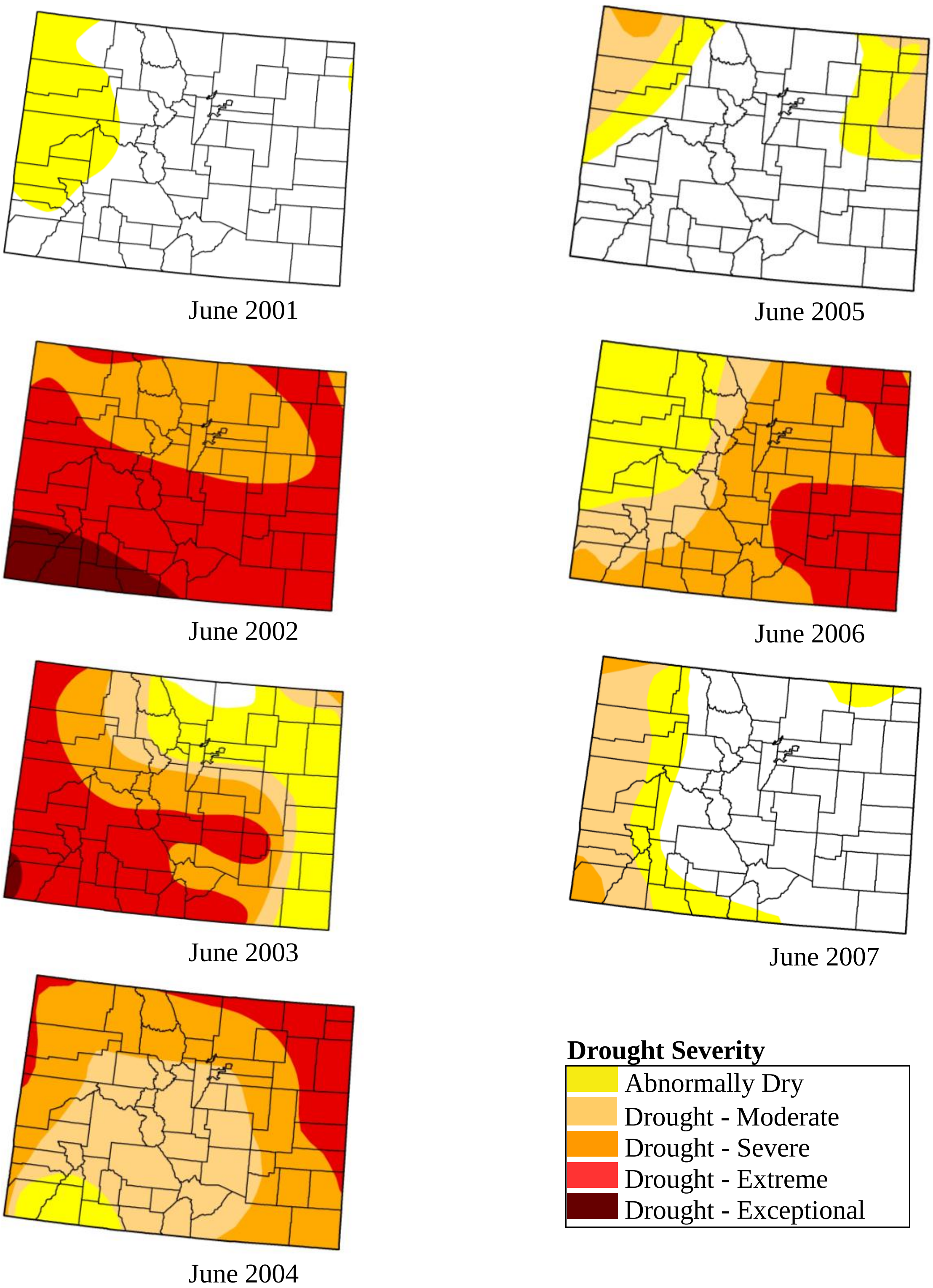

Figure 3. Drought status of Colorado for the period 2001 to 2007 as determined in June during the growing season. Images for 1999 and 2000 for Colorado are not available but national images depict abnormally dry conditions for the year 2000 at SAND, but not for 1999.

Strategies for Managing Black-tailed Prairie Dogs at SAND and on the Adjacent Private Lands

Management of black-tailed prairie dogs at SAND is needed to sustain the viability of the complex, avoid undesirable changes to the plant community at SAND, and to maintain favorable relationships with surrounding landowners. There are a number of lethal and nonlethal options available for managing prairie dogs including:

- use of vegetative barriers and/or grazing management adjustments to establish vegetative barriers,
- conservation easements,
- the use of fencing and other visual barrier techniques,
- live trapping and translocation of prairie dogs,
- directed shooting to site-specific areas, and
- use of approved rodenticides to control prairie dog populations.

Prairie dog populations rebound quickly after crashes because fecundity and recruitment of the remaining individuals is enhanced (Hooglund 2006). For this reason, preventing expansion of the prairie dog complex at SAND onto the adjoining private land will require a long-term commitment in resources and funding by the NPS.

Vegetation Barriers and/or Grazing Management

Barriers constructed of natural vegetation have been used to discourage the expansion of prairie dog colonies. This method is based on the fact that prairie dogs require a visually unobstructed landscape and prefer areas where vegetation is less than 30cm in height (Franklin and Garrett 1989, Roe and Roe 2003, Terrall 2006). Natural dense vegetation (e. g. shrubs) that are 40 cm or greater in height and that are between 80 and 103 m in width, proved effective in reducing colony expansion into adjacent areas (Crosby and Graham 1986, Truett and Savage 1998, Roe and Roe 2003, Terrall 2006).

Limitation or postponement of grazing has been reported as an effective technique for controlling colony expansion. Deferral of grazing from May to September can reduce prairie dog population growth rates, population density, and the surface area occupied by the colony (Snell and Klavachick 1980, Schenbeck 1985, Cable and Timm 1987, Reading and Matchett 1997). A major limitation of deferred grazing is that the effects are most pronounced in mixed and tallgrass prairies, while benefits in shortgrass prairie are meager (Hygnstrom 1994, Hooglund 2006) and possibly nonexistence during periods of drought.

Conservation Easements

When managers are concerned with the expansion of prairie dogs from public lands onto adjacent private lands, then these adjoining private lands should be considered for financial incentive payments or prairie dog easements to enhance existing, contiguous colonies (Cooper and Gabriel 2005). Landowner incentive programs could provide an economic incentive to landowners who agree to maintain or expand occupied prairie dog habitat. The goal of any incentive program should be for native grassland conservation and to achieve long-term persistence of the ecosystem, prairie dogs, and allied species (Luce 2003). Such a program would benefit economic sustainability in the region, by compensating private landowners who voluntarily agree to maintain native grasslands and not to control prairie dogs or significantly alter their habitat within agreed-upon areas (Luce 2003). Livestock grazing and other compatible uses could continue on lands under contract.

Fencing and Other Visual Barriers

Artificial visual barriers have afforded varying rates of success and are not as effective as natural vegetation in preventing expansion of colonies (Franklin and Garrett 1989, Hygnstrom 1995, Merriam et al 2004, Foster-McDonald et al. 2006). Franklin and Garrett (1989) reported that burlap fencing and felled ponderosa pines (*Pinus ponderosa*) were successful in preventing expansion of prairie dog towns, but maintenance costs made their use prohibitively expensive. Other research using a variety of materials including silt fencing, galvanized sheet metal and polyethylene plastic mesh fencing found that these materials were unsuccessful in preventing colony expansion (Hygnstrom 1995, Merriam et al. 2004, Foster-McDonald et al. 2006). A major problem with using artificial fencing as barriers is durability - they are badly damaged by wind, ungulates, and cows. The polyethylene mesh fencing that has proven durable (Merriam 2004, Foster-McDonald et al. 2006) has not been effective in controlling colony expansion (Hygnstrom 1995, Foster-McDonald et al. 2006). This may be because the see-through visibility of mesh fencing is 60%. Use of solid materials that increases visual occlusion may improve effectiveness (Hygnstrom 1995), but to the authors knowledge this has not been tested.

Live Trapping and Translocation of Prairie Dog Populations

The translocation of prairie dogs is a very resource-intensive endeavor. A number of issues must be dealt with for translocations to be successful including selection of suitable release sites, capturing and transporting animals, preparing release sites with attendant soft release infrastructure, and monitoring and managing animals (Truett et al. 2001). Soft release infrastructure includes retention baskets or fenced enclosures, sometimes combined with artificial underground nest chambers, which all help to reduce dispersal and predation (Truett 2001). Release sites must be carefully selected. The most successful sites have short vegetation (<12 cm tall) and pre-existing burrows; sites without these qualities may need modification such as creation of artificial burrow cavities (Hooglund 2006). Translocation of prairie dogs into areas without preexisting burrows results in survival rates of between 0-40%, rates that are unacceptable under most circumstances (Truett 2001). Control of predators may be needed prior to or following release. Post-release monitoring to detect and remedy potential problems such as dispersal and predation is recommended, and providing a food subsidy may reduce dispersal and elevate survival (Truett et al. 2001). The time and costs needed to accomplish the requirements necessary for successful translocation make this strategy difficult to implement. In addition, suitable nearby recipient sites are usually absent or available only in small number, limiting the utility of this management technique (Hooglund 2006).

Directed Shooting to Site-Specific Areas

Shooting reduces the size and density of prairie dog colonies and may have potential as a management tool (Hooglund 2006). Continuous shooting can remove up to 65% of the individuals from a colony, but shooting must be repeated annually, there are safety concerns, and the general public's acceptance of this method is uncertain, making shooting an impractical strategy (Hygnstrom 1994, Vosburgh and Irby 1998). Also, shooting can never be used to completely eliminate a colony because a portion of the population becomes wary and gun-shy making them impossible to shoot.

One benefit of this method is that harvested prairie dogs can be used to supply food resources to captive ferret rearing programs and raptor rehabilitation centers.

Use of Approved Rodenticides to Control Prairie Dog Populations

Rodenticides, particularly zinc phosphide, have proven effective in controlling prairie dog colonies with 66% to 97% of individuals being removed after pre-baiting (the removal rate falls to 30% to 73% in absence of pre-baiting). Zinc phosphide is most effective if used in late summer or early fall when prairie dogs are still very active and the availability of green forage is limited. Zinc phosphide, is a restricted use pesticide that requires users to be certified by the United States Environmental Protection Agency (EPA). Successful control requires about 400 grams of toxic oats per hectare with 4 grams spread at the base of every burrow-mound and entrance (Hooglund 2006). Zinc phosphide is not retained in tissues and should not kill scavengers feeding on poisoned prairie dogs, nor does it appear to harm many birds and mammals that frequent prairie dog towns, but it will kill seed-eating birds and mammals including some songbirds, squirrels, chipmunks, and rabbits (Hooglund 2006).

Fumigants, including aluminum phosphide and gas cartridges, are also very effective at controlling prairie dogs, but they are not recommended as the main means of control because of cost and the hazards to desirable non-target wildlife including burrowing owls, American badgers, prairie rattlesnakes, rabbits, and other non-target species (Hygnstrom 1995, Hooglund 2006). Fumigants cost between $30 and $40 per acre, which is three to four times the cost of zinc phosphide treated-grain baits (Virchow et al. 2002). For this reason zinc phosphide is considered the better alternative.

Population Densities Appropriate for the Acreage of Suitable Prairie Dog Habitat at SAND

Normal densities of prairie dogs are about 20 adult, yearlings and juveniles per acre as measured in May and June when juveniles first appear above ground (Hooglund 2006). This density represents the mean number of prairie dogs found within a colony whether it is an older colony not presently expanding or a younger expanding colony. This number, 20 per acre, does not necessarily represent the desired density for the prairie dogs at SAND.

There are 2,486 acres of shortgrass prairie present within the current established boundary of SAND and 1,196 acres of reclaimed agricultural land for a total of 3,682 acres of grassland suitable for prairie dogs (Neid et al. 2007) (Figure 4). If all 3,682 suitable acres were occupied at 20 prairie dogs per acre there would be a total of 73,640 individual prairie dogs at SAND. This number represents a population where all peripheral habitat along the fence-lines of the Park's boundary would be occupied by prairie dogs, which would allow for dispersal of these peripheral prairie dogs onto the adjacent private land. A buffer strip of 100m maintained free of prairie dogs along the outside boundaries of the Park within the shortgrass prairie and reclaimed agricultural land would remove approximately 170 acres of suitable habitat leaving 3,512 acres available for habitation and at 20 prairie dogs per acre there would be 70,240 individuals. Present estimates of prairie dogs at SAND are 15.4 per acre with 228 acres of occupied habitat for a total estimate of 3,511 individuals (Sovell 2007). At this density the population in the southern colony has reduced the vegetative cover and increased the cover of bare ground, which is common with the intensity of grazing associated with prairie dogs (Archer et al. 1987). Although the implications of long-term control to prevent dispersal into the surrounding private land is unknown, it is reasonable to expect that high densities of prairie dogs restricted to the same area, overtime will cause declines in habitat quality and resource abundance (Johnson and Collinge 2004). The exact density of prairie dogs that will avoid these declines in habitat quality is unknown. I suggest that the prairie dog colony at SAND be maintained at a density of 10 prairie dogs per acre, and that monitoring be implemented to identify whether there are adverse changes in the vegetation structure within the prairie dog complex. For a discussion of the adverse changes that can be expected, see the next section of this report. I also suggest that at the edges of the prairie dog colonies a 100 m buffer be maintained along fence lines adjoining private lands and that this buffer be planted with a dense cover of native vegetation greater than 40cm in height (e. g. rabbittbrush (*Chrysothamnus nauseosus*) or sandsage (*Oligosporus filifolia*) (Figure 4)). Control of prairie dogs in this 100 m buffer should be augmented with control administered throughout the colony that will reduce prairie dog densities to 10 individuals per acre. This would result in a total population of 35,120 individuals inhabiting 3,512 acres at peak occupancy.

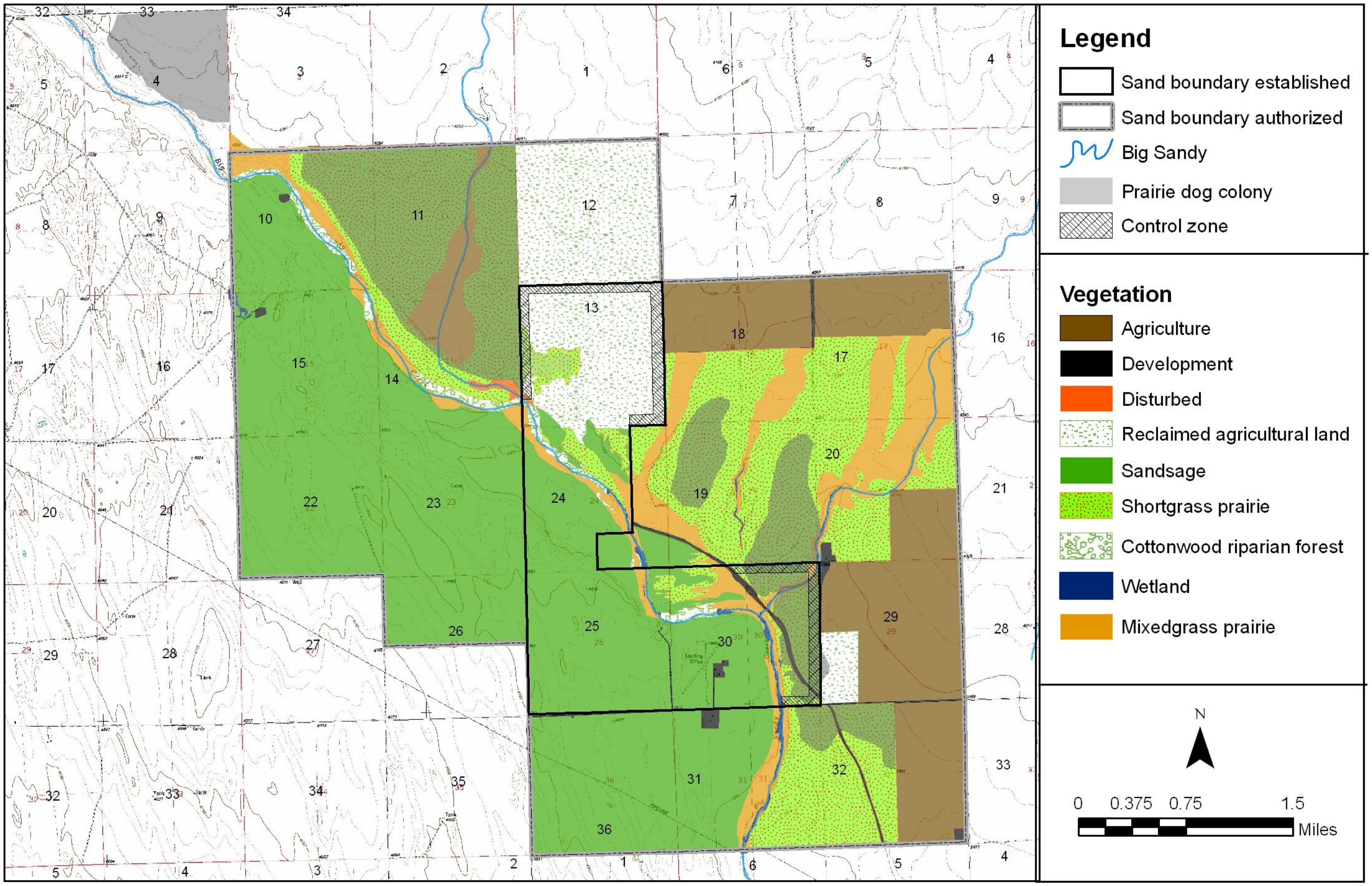

Figure 4. Vegetation map of Sand Creek Massacre National Historic Site with identification of prairie dog control zones where rodenticide will eliminate occupation and native vegetation will be planted to dissuade dispersal of prairie dogs onto adjacent private land.

The Potential Future Impacts Resulting from Prairie Dog Control

Future Changes in Prairie Dog Population Sizes

Interviews with private landowners and review of aerial photography for the area indicate that over the last decade prairie dogs have been expanding within the area authorized for SAND. It is likely that if The Park does not undertake control efforts the complex would continue to expand. Black-tailed prairie dog complexes are capable of exhibiting rapid rates of expansion and individual colonies show dramatic increases in size over short periods (Uresk and Schenbeck 1987, Garret and Franklin 1989, Hooglund 1995). It is likely that the prairie dog complex at SAND would continue to expand in the absence of control efforts designed to prevent its growth.

To the author's knowledge, plaque has never been reported in the immediate area of SAND, but prairie dog populations within the larger area surrounding SAND near Sheridan Lake and Swede Lake have experienced plaque-induced declines (Scherler pers. comm.). Plaque can cause severe declines in both prairie dog numbers and the size of area occupied, with colony area declining by as much as 89% and numbers declining by as much as 95% (Pauli et al 2006). If plaque were to infect the prairie dog complex at SAND, the complex would likely experience severe declines within one year (Pauli et al 2006).

Future Expansion Dynamics of Prairie Dogs after Control is Implemented

Control efforts on the part of the NPS are likely to create a dynamic that should favor rapid recovery of the complex to pre-control population sizes, because those prairie dogs removed from the population will result in more resources for newborns to exploit, ultimately increasing the success rate for recruitment of newborns. Following population control, intraspecific competition for forage and space decreases, and density-dependent regulation should be minimal (Pauli et al. 2006). Because of the abundant resources, individuals within a controlled colony should enjoy greater reproductive success and survival, mature more rapidly, and reproduce earlier, all of which will cause the population to experience rapid growth (Garrett et al. 1982, Rayor 1985, Pauli et al 2006). For this reason, populations rebound quickly after crashes, whether induced naturally or through control, because fecundity of the remaining females and recruitment of newborns is enhanced (Hooglund 2006). The size of colonies being controlled can expand by 30% per year for several years following control, however, if control is particularly intense increases of 71% can occur for one or two years post-control (Uresk and Schembeck 1987, Hooglund 2006). Analysis of the mean rates of fecundity and survival for black-tailed prairie dogs suggests colony abundance would require reductions of 55% per year to maintain populations at the prior level (Crosby and Graham 1986). In populations that have been reduced by 75% or more, recovery to pre-control population sizes requires 3 to 5 years (Crosby and Graham 1986, Knowles 1986). Because of the rapid rate that prairie dog populations can recover from control, preventing expansion of the prairie dog complex at SAND onto the adjoining private land will require a long-term commitment in resources and funding by the NPS.

Changes to Local Plant Community Structure within the Confined Colonies

Plant communities subjected to excessive grazing, such as that which occurs in prairie dog colonies, undergo an obligate change in plant community composition (Bonham and Lerwick 1976, Archer et al. 1987, Johnson and Collinge 2004). In shortgrass prairie, prairie dogs cause a shift to perennial warm season grasses such as buffalograss and purple threeawn (*Aristida purpurea*), an increase in forbs (which in time can become the dominate cover type), reductions in canopy height to half that of nearby uncolonized grassland, and increases in plant species diversity (Whicker and Detling 1988, Winter et al. 2002). Prairie dog effects on plant composition reflect the cumulative impacts of grazing intensity and grazing duration (Whicker and Detling 1988). As both the density of prairie dogs and the duration that the colony has been active increases, the changes to the grassland becomes more pronounced. It is at intermediate levels of disturbance, when occupation has been for an intermediate length of time and impacts are moderate that plant species diversity is maximized. As grazing severity increases (either intensity or duration) both species diversity and grass cover declines, while forbs become more dominant (Whicker and Detling 1988). This is not a problem when prairie dog movements within the landscape are not restricted, because prairie dogs will leave areas they have impacted through intense grazing and will colonized adjacent unoccupied habitat. The small scale movements of the colony that are continually occurring allows for impacted areas to recover before they are reoccupied by prairie dogs and once again grazed (Hooglund 2006).

When prairie dog movements are restricted either through control programs or by urbanization, they will continually populate the remaining suitable habitat at high density (Johnson and Collinge 2004). Highly impacted prairie dog colonies in urban areas provide superior environments, relative to non-colonized areas, for many native and introduced weedy species (Larson 2003). In these urban areas, grazing by prairie dogs creates bare and disturbed soils, conditions that may provide "safe sites" for weedy species that can avoid or tolerate prairie dog herbivory, such as Russian thistle (*Salsola* spp.), kochia (*Bassia scoparia*), diffuse knapweed (*Acosta diffusa*), and field bindweed (*Convolvulus arvensis*) (Rondeau 2005, Walsh Environmental Scientists and Engineers 2005). In time, invasive grasses, weedy forbs, and other non-native herbaceous plants dominate urban colonies (Walsh Environmental Scientists and Engineers 2005). It is reasonable to suspect the same would occur in colonies undergoing control.

In summary, if management actions restrict the prairie dogs to continued occupation of SAND's suitable prairie habitat, then over time the SAND complex will exhibit increased cover of the warm season grasses buffalograss and purple threeawn, a general decrease in perennial grass cover, a corresponding increase in the cover and diversity of forbs, and establishment of introduced weeds. Avoiding this change in plant community composition will require maintenance of prairie dog numbers at low density; however, there is no information identifying at what density prairie dogs will not degrade the habitat. Consequently, it is recommended that SAND maintain its prairie dog population at 10 individuals per acre, half the mean colony size estimated for prairie dogs, and that monitoring be implemented to verify that plant species composition is not changing.

The Recommended Management Action

I recommend as the preferred alternative a combination of lethal control using zinc phosphide-treated grain baits and the planting of tall, dense natural vegetation to dissuade colony expansion onto adjoining private lands. Zinc phosphide baits should be used in the fall when prairie dogs are still active and green forage is limited and after pre-baiting, which improves efficacy.

I recommend that SAND maintain its prairie dog population at 10 individuals per acre, half the mean colony size estimated for prairie dogs, and that monitoring be implemented to verify that plant species composition is not changing within the complex.

I also suggest that at the edges of the prairie dog colonies a 100 m buffer be maintained along fence lines adjoining private lands. The buffer should be planted with a dense cover of native vegetation greater than 40cm in height (e. g. rabbittbrush (*Chrysothamnus nauseosus*) or sandsage (*Oligosporus filifolia*)) (Figure 4). Complete elimination of prairie dogs in this 100 m buffer should be augmented with control administered throughout the colony that will reduce prairie dog densities to 10 individuals per acre. The south colony is already expanding onto the adjacent private land while the north colony is not. Consequently, construction of the natural vegetation barrier should be initiated on the south colony and expanded to the north colony as funding and time permits or at such time as the north colony does threaten expansion onto adjoining private land.

Monitoring Protocols Required to Identify Future Impacts of Prairie Dog Control

Prairie Dog Monitoring

Monitoring should be undertaken to ensure that the control program is maintaining prairie dog density at the stated goal of 10 individuals per acre. Monitoring of black-tailed prairie dogs will be accomplished using the protocol developed for seven national parks (Severson and Plumb 1998, Plumb et al. 2001). Sampling should be conducted annually if the intent is to measure yearly variations in density or three times per decade if the purpose is to measure broader scale trends in population size over a 10 year period (Plumb et al. 2001). I suggest that sampling should occur every year for the first three years after control is implemented and if densities appear stable, then at three year intervals over the next 10 years. Sampling should be conducted in June or July after emergence of young from burrows, but before young-of-the-year disperse. Severson and Plumb (1998) found that visual counts of prairie dogs, using maximum rather than mean values, on 4-ha plots were significantly related to estimates of density from mark-recapture techniques. The best model defining the relationship between maximal counts and estimates from mark-recapture studies was $Y = 3.04 + 0.40X$, where Y is the maximum visual count and X is the estimated population density. The inverse of this equation $X = (Y - 3.04)/(0.40)$, is used to index numbers of black-tailed prairie dogs from visual counts. Researchers have concluded that density estimates based on maximal visual counts can be used to compare prairie dog density among years (Menken et al 1990, Severson and Plumb 1998).

The field methodology will follow the sampling approach of Plumb et al. (2001). This method requires setting up a 200 m x 200 m (4-ha) plot in each prairie dog colony and conducting visual counts of prairie dogs. Plots must be established 24 hours prior to conducting counts in order for prairie dogs to return to normal behavior following the intrusion of people walking through the colony. Visual counts are conducted on the 4 ha plot using binoculars with four counts taken on each of three consecutive days. Boundaries of the 4 ha plot are delineated using fluorescent orange stakes and counts are initiated after waiting 30 minutes before beginning the first count, with 15 minutes between counts (Plumb et al. 2001). The maximum count of prairie dogs recorded over the 12 samples (4 counts/day x 3 days of counting) is used in the equation of the previous paragraph to estimate colony density. This estimate is then compared to the control goal of a density equal to 10 prairie dogs per acre.

Vegetation Monitoring

In order to detect changes induced by prairie dogs in plant species canopy cover, composition, density, and frequency over time, randomly-chosen permanent vegetation monitoring plots should be established. Ideally, eight plots should be monitored, two in each of the prairie dog colonies and four paired plots in grassland without prairie dogs acting as controls. It may not be possible to find four areas for control plots without going outside of the park boundary to locate plots. Working with landowners may prove difficult and it may be necessary to reduce the number of control plots. Depending upon the temporal scale desired for identifying changes in plant community structure, plots should be sampled either once each year or three times per 10-year period. I suggest that sampling should occur every year for the first three years after control is implemented and if species compositions appear stable, then at three year intervals over the next 10 years.

Plot Design

A stake is placed at the center of each plot. Four transects are then established at each plot by placing flexible 50 m tapes along the cardinal directions and marking the beginning (center of plot), middle, and end of each transect with two-foot rebar (Figure 5).

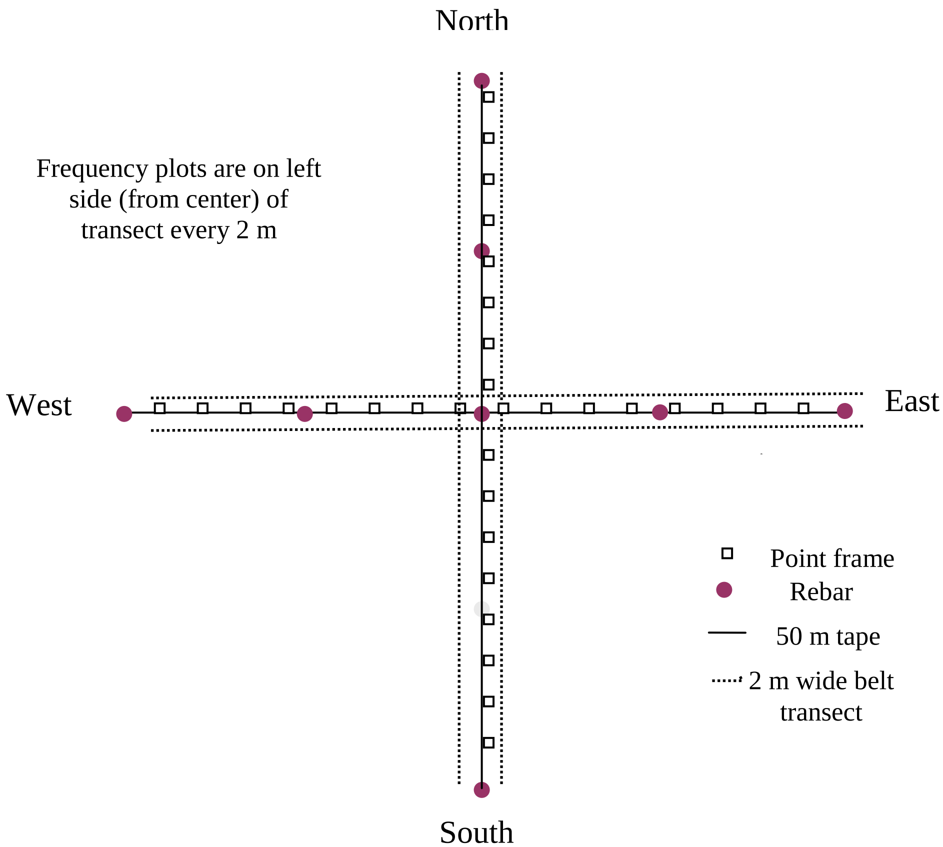

Figure 5. Configuration of a vegetation sampling plot.

Shrub canopy cover is estimated using the line-intercept method along each of the four transects with 1 cm increments (Bonham 1989). Within the canopy of a plant, gaps in live green vegetation less than 10 cm in length are considered to be continuous cover.

To estimate canopy cover of grasses, forbs, litter, and bare ground, eight point-frames (or microplots) (Bonham 1989), each 55 x 30 cm with 50 points (each point 5 cm apart) are placed every 5 meters along each of the four 50 m transects (Figure 5). The first frame placement is randomly selected, then each subsequent frame is placed 5 m from the preceding one. Only green to light green plants are measured as live grass or forb cover. Dead plants including standing dead (usually brown in color), ground litter, or stump remains of grass clumps are recorded as litter. Bare soil, macrophytic crusts, or pebbles are considered bare ground. Shrubs are not recorded in the microplot because shrub cover is measured using the line-intercept method (see preceding paragraph). The ground cover below shrubs (e.g. grass, litter, or bare ground) in a microplot is recorded as cover for that location. The canopy cover of grasses, forbs, litter, and bare ground should sum to 100%. In wet years, it is possible to have greater than 100% cover within a microplot because forbs (e.g. Russian thistle) often form an overstory with blue grama or other species growing beneath.

A 50 m x 2 m belt transect is used to measure shrub density (Bonham 1989). This is accomplished by measuring a 1 m band on both sides of each 50 m transect (Figure 5). Any shrub that has vegetation within this area is counted - i.e., the shrub does not have to be rooted within the area. To avoid double counting at the center point of the site, only the north and south transects in the region of overlap are counted.

Frequency of dominant or indicator species is measured with 25 nested-frequency plots per 50 m transect (Elzinga et al. 1998) placed every 2 m on the left side of the transect (as viewed from center stake) beginning at the 2 m mark. The appropriate plot size for detecting statistical differences in the frequency of a species is influenced by the density and dispersion of that species within a community (Hyder et al. 1965 as cited in Winter et al. 2002). Small plots sample the dominant species (e.g. blue grama grass) at optimal frequencies, but fail to detect less common species. Three different plot sizes (nested frequency plots) should be used to measure frequency because concurrent use of small and large sizes ensures adequate sampling of both common and uncommon species (Hyder et al. 1975 as cited in Winter et al. 2002). The nested-frequency frame sizes used are as follows: a) 0.1 m x 0.1, b) 0.31 m x 0.31 m, and c) 1 m x 1 m. The 0.1 m x 0.1 m and 0.31 m x 0.31 m frame sizes are placed in the lower left corner (as viewed from center) of 1 m x 1 m plot. The species included in the nested-frequency plots should include the dominant species like three-awn grass and blue grama.

Reference photographs should be taken from both ends of each transect (landscape views) as well as at the 3rd and 5th microplots (views looking straight down).

Monitoring of the black-tailed prairie dog population and the vegetation cover within the prairie dog complex at SAND will allow The Park to measure how successfully control is maintaining prairie dogs at the target density and avoiding changes to the native character of the plant community. Understanding how prairie dog density influences vegetation plot dynamics will help to define trends in how prairie dog population size influences plant community structure; something that to the author’s knowledge has never been measured. Information from the monitoring program will assist with adaptive management of the natural resources at SAND. If the desired target density for prairie dogs results in unfavorable changes to the plant community, the target density can be adjusted lower and subsequent monitoring used to measure whether the new density effectively preserves the native cover of vegetation.

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